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Equipment Systems Improvement Program – Development

Feasibility Study
Remote Vehicle Disabling Systems

Prepared by
LAW ENFORCEMENT DEVELOPMENT GROUP

9 April 1973

Prepared for
LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
U.S. DEPARTMENT OF JUSTICE

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THE AEROSPACE CORPORATION

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EQUIPMENT SYSTEMS IMPROVEMENT PROGRAM -- DEVELOPMENT

FEASIBILITY STUDY
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Prepared by

Law Enforcement Development Group
THE AEROSPACE CORPORATION
El Segundo, California

9 April 1973

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EQUIPMENT SYSTEMS IMPROVEMENT PROGRAM--DEVELOPMENT

FEASIBILITY STUDY: REMOTE VEHICLE DISABLING SYSTEMS

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ABSTRACT

A remote vehicle disabling system concept that would allow a police vehicle to slow or stop a pursued vehicle is investigated. The system conceptualized includes a transmitter in the police vehicle and a receiver and disabling device in the pursued vehicle. Preliminary analysis indicates that the ability to "select" a unique offending vehicle is a major design constraint and that the ignition system is most compatible with disabling device requirements. A logic discrimination circuit in the disabling device is conceived to satisfy the selectivity requirement. Use of the circuit for other purposes is feasible. Technical and economic issues affecting system feasibility limited the study to providing a more detailed and quantitative definition of critical system parameters. Although the technology exists for hardware development and demonstration of the system, it is concluded that the data to fully evaluate the related economic issues are not available. From the minimum financial data available on pursuit-related crashes, an "acceptable" system cost varies from $9 to $74.

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The following technical personnel of The Aerospace Corporation participated in the study effort performed under this contract:

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SUMMARY

This report, prepared by The Aerospace Corporation for the Law Enforcement Assistance Administration, describes a task intended to result in the development and demonstration of a remote vehicle disabling system concept. The system was to be activated from a police patrol vehicle to cause a pursued public vehicle to slow down or stop. Preliminary analysis indicated that modification of the public vehicle was required and that the system elements would comprise a receiver and disabling device in the public vehicle and a transmitter in the police vehicle.

Early in the study, requirement-related technical and economic issues developed which caused the feasibility of the system to be questioned. As a result, the hardware development and demonstration task was deferred and the effort was redirected to provide a more detailed and quantitative evaluation of system parameters in order to determine their criticality with respect to these issues.

One issue in question involved the function of selecting a single vehicle from a group of vehicles, a function required in order to not jeopardize law-abiding drivers. While it was initially assumed that the communication link could select a single vehicle, it was found that this approach would adversely affect both the cost and functional capability of the system. This led to a logic discrimination circuit concept which would differentiate between a law-abiding and a pursued vehicle by sensing vehicle parameters and detecting characteristic differences. This new concept permits the use

of a simple and low cost communication link and also enhances the performance capability of the vehicle disabling device. In addition, the logic circuit could be used to expand the system capability to perform other functions, such as alerting drivers to the presence of <u>any</u> emergency vehicle.

A second issue in question involved an initial assumption that the system benefits were those resulting from an improved capability to apprehend criminals attempting escape from pursuing police vehicles, and a reduction in hazard to the public during the chase of those criminals. Since all of the disabling concepts originally considered could be defeated in advance of a pursuit by any determined individual, given sufficient time and motivation, the practicality of achieving these benefits was questioned. From further study, however, it was found that a large percentage of pursuit chases are initiated by a minor traffic violation and involve young (under age 24) drivers. Since the circumstances that initiate these chases are generally not premeditated and do not normally involve a criminally motivated individual, it is highly improbable that, in most of these cases, the disabling device would have been previously rendered inoperable. Thus, the true benefits of the system would be the economic and social benefits resulting from the elimination of crashes and casualties during the pursuit of non-criminals. This affected the system requirements by placing priority on the functional capability of the system to prevent the attainment of high speeds during pursuit and to slow down and stop the pursued vehicle in a safe and controlled manner.

The third issue involved the economic feasibility of the system. This was initially questioned, primarily because of the enormous cost to implement any system that would involve over 100-million public vehicles and, secondarily, because of the limited benefits that were initially thought to exist. With the subsequent clarification of the system benefits, however, it was possible to determine an acceptable system cost by equating it to the societal cost of noncriminal pursuit crashes and casualties that would otherwise occur. From this study it was found that a system cost of $21 per vehicle would be commensurate with its benefits. This, however, is based on a "best estimate" of the number of pursuit-related crashes and casualties from a Department of Transportation report. Because of uncertainties in the number of pursuit-related crashes and casualties that actually occur each year, the acceptable system cost might be as low as $9 but could be as high as $74 per vehicle. The cost effectiveness of the system might be improved, or higher system costs permitted, if other potential benefits from the system, such as the capability to warn drivers of the presence of other emergency vehicles or the reduction in insurance premiums resulting from fewer crashes and casualties, were to be included in a cost/benefit study.

Conceptually, a device could be employed to disable a vehicle by overriding any system whose function is essential for normal operation. The ignition system is preferred, however, on the basis of its compatibility with system performance and cost requirements. The disabling modes could be a circuit interrupter to limit the number of spark plug firings, or an electrical resistor to limit the voltage delivered to the spark plugs. For either mode, this could be programmed within the device to progressively deteriorate engine power or, with a logic circuit, made variable to cause a high degree of engine deterioration whenever a significant increase in engine power is demanded. The cost of the logic circuit should be minimal since it could be shared by future automated maintenance and emission control systems that also require sensing of basic engine parameters.

This analysis has developed a remote vehicle disabling system concept which appears to be technically feasible. The question of economic feasibility is dependent upon a better definition of the total benefits which such a system could provide. These include benefits from the reduction in deaths and injuries caused by high speed pursuits and similar benefits from the reduction in accidents associated with other emergency vehicle operations. The cost to the public of the system can be reduced if the sensors required by pollution controls, and possibly automated vehicle maintenance, are also used for inputs to the logic discrimination circuit of the disabling device. The installation of this device could result in a reduction in insurance premiums, particularly for the young male driver, making it more acceptable to the public.

CHAPTER I. INTRODUCTION

The Aerospace Corporation, under contract to the Law Enforcement Assistance Administration (LEAA), undertook the task to develop and demonstrate a conceptual vehicle disabling system which could be activated from a police patrol vehicle to cause a pursued vehicle to slow down or stop. Since this was one of the original tasks assigned in the Equipment Systems Improvement Program, the normal Requirements Definition Phase by the Analysis Group had not been accomplished. A number of remote vehicle disabling concepts not requiring public vehicle modification were initially investigated, but none were considered suitable. Therefore, it was accepted that vehicle modification was necessary and that the essential elements of the disabling system would be (1) a transmitter in the police patrol vehicle to provide the activation signal, (2) a receiver in all vehicles of the general public to accept this signal and to relay it to the disabling device, and (3) a disabling device, also in all public vehicles, to act on this signal to override one or more of the basic vehicle systems, causing it to slow down and stop.

Early in the study, requirement-related technical and economic issues which could affect the feasibility of the system became evident. As a result, the Task Plan was revised to defer the hardware development and demonstration and to limit the scope to only that effort required to provide a more detailed and quantitative definition of the critical system parameters. Concurrent with this task revision, a notification was placed in the Commerce Business Daily (CBD) seeking research and development sources for this system, with the plan that the critical system parameters derived from the revised task could be used to evaluate any concepts contained in the responses to this notification. However, the responses to the CBD notification did not provide a sufficient technical definition of system concepts to permit a meaningful evaluation.

The results of the evaluation of the requirement-related technical and economic issues, including the identification of critical system parameters, are presented in Chapter II. Transmission link concepts and a logic element, not previously considered, are discussed in Chapter III. This is followed by a discussion of vehicle disabling device concepts in Chapter IV.

CHAPTER II. SYSTEM REQUIREMENTS

A simple economic analysis of a remote vehicle disabling system by which a police vehicle can slow down or stop an offending public vehicle indicated a design which minimizes the equipment included in the public vehicle. Nevertheless, all practical systems conceived require some critical elements in the public vehicle. As conceptualized, the generic system consists of a receiver and disabling device in the public vehicle activated by a command system in the police vehicle.

Early in the system study, requirement-related technical and economic issues were encountered in the areas of system compatibility, benefits, and costs. Since these issues could affect system feasibility, the effort was redirected to provide a more detailed and quantitative evaluation of system parameters in order to determine their criticality with respect to these issues. The results from this evaluation are presented in this Chapter.

A. System Compatibility

The primary compatibility issue which developed related to the basic requirement that the disabling system should not jeopardize the safety of operation of or cause damage to law-abiding vehicles, nor unduly inconvenience their drivers. This requirement dictated that the system be selective such that only the pursued vehicle would be adversely affected when the disabling system is activated.

Originally, it was assumed that this selectivity requirement would have to be satisfied by the communication link. Two basic concepts were originally considered. One concept was a highly directional and highly attenuated signal from the police patrol vehicle that would activate only the pursued vehicle. The other concept used a coded signal that would activate only the vehicle(s) with that particular code. In both of these approaches there were technical and economic problems. In the highly directional signal concept, the beam would have to be carefully aimed and might be required to be steerable, making it difficult to operate in a one-man police patrol vehicle. This concept also required that the pursued vehicle be in the line of sight, making the communication link vulnerable to evasive action by the pursued vehicle. The coded signal system concept required a transmitter/receiver for each vehicle to provide the vehicle identity code. This more complex equipment would significantly increase the system cost. Additionally, unless this concept also used a highly directional signal, several vehicles might simultaneously be addressed, making it difficult to determine which reply to accept.

In the evaluation of the communication link constraints imposed by the selectivity requirement, it became apparent that this requirement could also be satisfied by the addition of a fourth element in the disabling system. This element could be a logic circuit within the disabling device on the public vehicle which would discriminate between a law-abiding and a pursued vehicle by the sensing of affected vehicle parameters. With this element, the signal transmitted from the patrol car would not have to be directional. In fact, it would be desirable that it activate the device in all public vehicles in the vicinity since, with the logic circuit, a warning light or buzzer could be triggered to alert all drivers to the presence of an emergency situation, while discrimination by the logic circuit would permit the disabling device to be triggered only in the pursued vehicle.

One approach that could be used in arriving at the appropriate logic is to utilize the difference in response by a law-abiding versus pursued driver when alerted to a pursuit condition. Typically, the law-abiding driver would close the engine throttle in order to slow down and move over. The opposite reaction would be expected from the pursued driver. Since manifold pressure is a function of throttle setting, the existence of a high manifold pressure (wide open throttle) could be used to identify the pursued vehicle. By sensing this pressure, and/or other appropriate vehicle parameters, the logic circuit could differentiate between the two cases and cause the disabling device to be activated only on the pursued vehicle. Refinements, such as inhibit circuits, however, would probably be required to take care of contingency situations. For example, a time delay circuit could be used to provide the temporary power needed by a law-abiding driver to perform evasive action.

The addition of a logic circuit as a fourth element in the disabling system would, of course, introduce some additional system cost. With the electronic technology currently available, however, these costs would be minimal and would probably be more than offset by the potential benefits which could result from the logic circuit's capability to perform other functions such as alerting drivers to the presence of <u>any</u> emergency vehicle.

B. System Benefits

Initially in the study, it was considered that the benefits from the disabling system would result from an improved capability to apprehend criminals attempting escape from pursuing police vehicles and a reduction in the hazard to law-abiding drivers during the chase of those criminals. On this basis, it was assumed that the disabling device on public vehicles would have to be invulnerable to deactivation. Since all of the disabling concepts originally considered could be defeated beforehand by any determined individual, given sufficient time and motivation, the practicality of the system was questioned.

In the course of a search to better understand this anti-deactivation requirement, some pertinent statistics were found.[1] These statistics indicate that more than 90 percent of pursuit chases are initiated by a minor traffic violation and involve young (under age 24) male drivers. In more than half of these cases alcohol is involved and the offender has at least one prior license suspension. Since the circumstances that initiate these chases are generally not premeditated and do not normally involve a criminally motivated individual, it is improbable that even an easily defeated disabling device would have been previously rendered inoperable on most of these vehicles. Moreover, if the disabling device were reasonably difficult to defeat, and if there were severe penalties associated with its deactivation, it is even more improbable that the device would be inoperable on those vehicles which are most likely to be involved in a pursuit.

The above statistics lead to the realization that the true benefits of the disabling system would be those that result from the elimination of or significant reduction in the number of pursuits of noncriminals and pursuit-related casualties and crashes. This change in the expected benefits, then, imposes a different system requirement to limit both the speed attained during a pursuit and its duration, and to provide a means to slow or stop the pursued vehicle in a controlled and safe manner. This different system requirement de-emphasizes the need for a deactivation-proof disabling device, although the addition of a logic circuit element to the system now makes it possible for this requirement to be more nearly achieved. With additional sophistication, the design of the disabling system including the logic circuit could be such that it would be very difficult to defeat.

C. System Cost

Since the initial phase of the study indicated that the disabling system would provide only doubtful benefits and that its implementation would cost the public many millions of dollars, the economic feasibility of the system was seriously questioned. With the subsequent clarification of system benefits, however, it is now possible to more quantitatively evaluate this economic issue.

It is axiomatic that system benefits must be in reasonable balance with system costs. In this case, the benefits would be the significant reduction in or the elimination of pursuit-related crashes, and the dollar value of these benefits would be the societal cost that otherwise would have been incurred from the deaths, injuries, and property damages resulting from

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Statistics of pursuit crashes and resultant casualties are given in a recent Department of Transportation report.[1] Unfortunately, the statistics on this subject are very limited and sometimes inconsistent. A "best estimate" taken from this report indicates that 7,000 pursuit-related crashes occur each year in which 350 people are killed and 3,750 receive some type of injury. This best estimate, however, has a lower bound limit of 2,000 crashes resulting in 100 deaths and 2,000 injuries, and an upper bound limit of 20,000 crashes resulting in 1,000 deaths and 15,000 injuries.

Another publication[2] provides data on the societal cost of motor vehicle accidents. The costs derived in this report are approximately $200,000 per death, $2,500 to $67,000 per injury (dependent upon severity), and $1,000 of property damage per accident involving injury. Since very high speeds are usually associated with pursuits, it would be expected that injuries resulting from pursuit-related crashes would generally be very severe. The cost per injury in this case would, therefore, be on the high side of the range given in the referenced report. Accordingly, $35,000 was assumed to be a reasonable cost for injury resulting from a pursuit-related crash.

The above statistics can be used to calculate the dollar value of the potential system benefits. For the best estimate case, the annual benefits would be $208 million, with a lower bound value of $92 million and an upper bound limit of $745 million. These benefits can be translated to an acceptable system cost by equating their annual dollar value to the annual cost of incorporating the disabling system in production vehicles

$$\text{Unit System Cost} = \frac{\text{Annual Benefits}}{\text{Annual Production}} \times \frac{\text{Annual Production}}{\text{Total Vehicles}} \times \text{Vehicle Life}$$

Since the annual vehicle production rate (ten million) is an approximately constant ten percent of the total vehicle population (100 million), and the average vehicle life is approximately ten years, these factors cancel each other such that

$$\text{Unit System Cost} = \frac{\text{Annual Benefits}}{\text{Annual Production}}$$

For the best estimate case, this would result in an acceptable system cost of approximately $21 per vehicle, with a lower and upper bound limit on this cost of $9 and $74, respectively.

Although the above system costs reflect progressive effectivity and resulting benefits, it would be a number of years before the system could be incorporated on most of the public vehicles. Figure 1 shows the percentage of vehicles that would be affected as a function of years in production. A much earlier effectivity, of course, could be obtained by retrofit of the disabling system to existing vehicles. Assuming that the retrofit cost might be twice the production cost, and amortizing this over 20 years, the acceptable system cost would have to be reduced to approximately two-thirds of the values given above.

It should be noted that acceptable system costs were derived on the basis that pursuit-related crashes and casualties would be completely eliminated. Obviously, the disabling system could only approach this goal. In

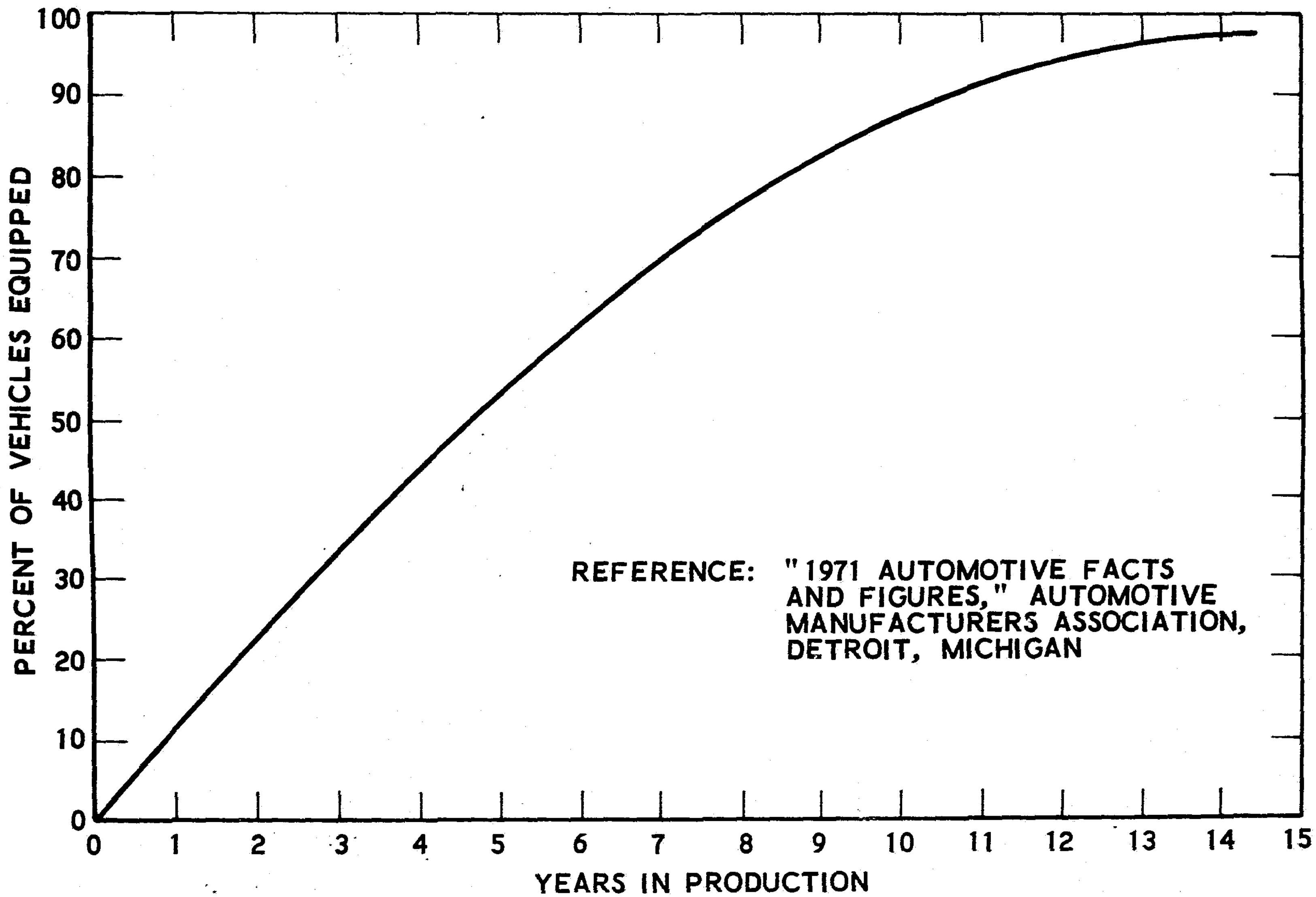

Figure 1. Percent of Vehicles Equipped Versus Years in Production

addition, interest and inflation factors were neglected. At this time, however, further refinement of this cost is not warranted because of the very large cost difference resulting from an uncertainty in the actual number of pursuit-related crashes.

It should also be noted that the above costs do not reflect other benefits that the system might provide. Since the disabling system, with only minor modification, could be used to alert drivers of the presence of <u>any</u> emergency vehicle, it could reduce the number of other emergency vehicle-related crashes and casualties. This potential should be investigated since it might provide significant benefits. In addition, the decreased incidence of crashes could result in a reduction in insurance premiums for the motorist.

CHAPTER III. COMMUNICATION LINK

Two major design constraints on the communication between the police vehicle and the offending public vehicle are equipment cost and the ability to select the unique offending vehicle alone. Additional requirements are the operating range, operational simplicity, and some immunity to unauthorized activation or disabling. The cost constraint is translatable into a limit on the complexity and availability of the components. The selectivity constraint controls the design concept to a great extent, and various candidate modes to satisfy that requirement are discussed below.

The selectivity can be accomplished by the communication link in two general ways: (1) illuminate only the selected car with the energy used for communications, and (2) use a coded message that will be decoded and accepted only by the selected vehicle. Selectivity can also be accomplished by the addition of another element in the system which could discriminate between a law-abiding vehicle and a pursued vehicle.

A. Directional Mode

If Mode (1) is employed, it is necessary to restrict the communication energy to a narrow beam so as to not interfere with ambient traffic. Narrow beam for the case of radio transmission requires that the transmitter antenna effective aperture be large with respect to the transmitted wavelength. This can be achieved with either large antennas or short wavelengths.

A short wave band for which there is an established technology is the 60 GHz band. The high atmospheric attenuation in that band will also automatically limit the effective range of the transmitter, and thus reduce any potential interference problems. At this frequency, beamwidths as narrow as ten degrees can be easily achieved with antennas having dimensions on the order of inches. Components in this frequency domain are within the state of the art, though not generally commercially available. It is estimated that a 60 GHz receiver with the required sensitivity and bandwidth could be produced at a cost of $10 to $20.

If acoustic energy is used as the communication carrier, the frequency can be reduced considerably for the same wavelength because of the much reduced velocity of propagation. For a wavelength equivalent to the 60 GHz radio frequency (0.2 inches), the acoustic frequency would be about 70 KHz. Again, the atmospheric attenuation is high so that secondary reflections and other modes of interference would be minimized. Advantages such as noninterference with existing radio communications, simple cheap components, and a technology which would be difficult for an unauthorized user to apply would be benefits of the acoustic carrier. Disadvantages are similar to those experienced by the radio frequency carrier in that a clear line of sight is required to the offending vehicle, and that a very narrow beam may be required that would possibly need accurate pointing by a person other than the driver of the police vehicle.

Visualization of the pointing accuracy would be almost impossible with either the radio or acoustic carrier, so that the operator would not know how well he is illuminating the offending vehicle. This problem could be relieved by using a carrier or laser in the visual or near-infrared band.

Again, narrow beams are possible with small apertures (lenses), and all of the characteristics of the narrow beam concept are continued with the exception that target illumination visualization is conceptually possible, though still difficult.

In summary, for Mode (1), the technology for implementation is available in at least three forms of carrier energy. Costs of the receiver components for all carriers can be considered to be less than $20 per unit. Major problems will be pointing and aiming the energy at the offender without bothering the general public.

B. Coded Mode

The second mode of selectivity considered is the use of a coded message that defines a unique public vehicle. Several techniques have been examined to operate in this mode. In general, the equipment consists of a programmable encoder in the police vehicle that can be switched to address a specific vehicle which contains its unique code decoder. The technology is available to produce such equipments. The major problem is the operational difficulty to determine the address of the offending vehicle so that it can be programmed in the encoder. Visual methods could include the use of the license plate, or similar tag, but this is considered to be clumsy at ranges over 100 feet under hot pursuit conditions, even with optical aids.

Electronic techniques have been suggested to identify each vehicle. The individual vehicle would emit its unique address when its receiver is illuminated. If only a single vehicle's receiver is illuminated at one time, this concept will work. However, if only a single receiver is to be consistently illuminated, then no electronic addressing is required. When several public vehicles are replying simultaneously, the police vehicle must choose the desired vehicle. This can be done on the basis of relative velocities between vehicles, but the complexity required in the police vehicle will add a significant cost increment. Though there are no technological barriers to this mode of operation, the operational problems appear severe and soluble only with relatively expensive equipment.

C. Logic Mode

The third mode of selectivity considered was the use of some internal characteristic of the offending public vehicle to logically combine with a police signal and provide the selection. This mode has one very important advantage in that the communication signal from the police vehicle can be very simple, narrow bandwidth, and wide beam. The frequency and form of the carrier need not be constrained by selectivity considerations and thus can be optimized for other parameters such as cost or operational simplicity.

The choice of the internal signal in the offending vehicle can be any that correlates with the conditions of hot pursuit. Such characteristics are the engine rpm, the throttle mechanism setting, the intake manifold pressure, the exhaust gas temperature, and the engine mass flow rate. All of these parameters can be correlated with high speed, or operator demand for high-speed automobile operation. These variables, properly sensed, can be combined to provide one input to a two-terminal logical "and" gate. The other terminal would be from the communication system as energized by a signal from the police vehicle.

In summary, for the third mode, the need for narrow beams or coded signals is relieved. The law-abiding vehicle would be alerted by but not adversely affected by the police communication signal. Equipment implementation in the police vehicle is expected to be low in cost and its operation would involve only the closing of a switch. The cost of the receiver in the public vehicle should be in the $5 to $10 range in large production quantities.

CHAPTER IV. VEHICLE DISABLING DEVICE

One of the disabling system elements is a vehicle disabling device which would be installed on all vehicles of the general public and, when activated, would cause a vehicle to slow down and stop. To satisfy the functional requirements, the device must react immediately to slow down and stop the vehicle in a safe and controlled manner without causing permanent damage to the affected vehicle system. Its reliability also must be at least equal to that of typical automobile components. To satisfy the system cost constraints, the design must be simple in order to minimize manufacturing costs. Secondary requirements are that the device be reasonably secure from deactivation, that it be accessible for inspection, and that it be capable of being retrofitted to existing vehicles.

A. General Concepts

In general, the slowing down and stopping of a vehicle can best be accomplished by an overriding control of one of the vehicle's subsystems whose function is essential for normal vehicle operation. The systems which fall into this category include the ignition, fuel, transmission, brake, and exhaust systems. Conceptually, a device could be employed to override any of these systems, but the one most compatible with a disabling device is the ignition system as discussed in paragraph IV.B. The primary disadvantages associated with concepts that might be used with the other systems are briefly discussed below.

Fuel System. Although any number of devices could be employed to shut off the fuel flow to cause the vehicle to stop, it would be very difficult to restrict the fuel flow in a manner that would introduce a controlled slowing down of the vehicle. Further, unless the fuel were cut off at the carburetor jets, the stopping of the vehicle would be delayed by the reserve of fuel in the carburetor float chamber.

Transmission System. Disengagement of the drive train could be employed to cause the vehicle to stop. While this could be effected by valves in an automatic transmission, its accomplishment on manual transmissions would be very difficult.

Brake System. While an override control of the brake system might be possible, it is difficult to conceive of a design that could slow down and stop the vehicle in a predictable and controlled manner.

Exhaust System. A valve or plug could be used to cause blockage in the exhaust system and might be an effective way to slow down and stop a vehicle. The environment in which it would have to operate, however, is quite severe and a device in this system could compromise vehicle reliability.

B. Preferred Disabling Concepts

The vehicle subsystem most compatible with all of the disabling device requirements is the ignition system. With the exception of diesel-powered vehicles, this system has a high degree of commonality in all make and model vehicles and its components are generally located in an accessible area which would facilitate installation, inspection, and replacement.

The fuel system, however, is more compatible with disabling diesel-powered vehicles and would probably be used to perform this function if it is required for these very limited numbers of vehicles.

The ignition system coil, which is approximately the same size and shape for all make and model passenger vehicles, is an ideal component in which to incorporate a disabling device. Since the coil contains a silicone oil, it is normally sealed and thus discourages tampering. In addition, an electrical power source for operation of the disabling device is assured since the engine will not function if the coil is not energized. Its installation or replacement involves only three electrical connections and one or two bolts which secure it to a holding bracket. Other electrical system components in which the disabling device could be incorporated are the distributor and the ignition controller, a new component being added to many 1975 model vehicles to assist in emission control.

All of these components are electrically interconnected with the primary ignition circuit. Disabling of the vehicle through this circuit could be accomplished by one of two modes: (1) a circuit interrupter to limit the number of spark plug firings, and (2) an electrical resistor to limit the primary current flow and thus limit the voltage delivered to the spark plugs.

1. Circuit interrupter mode. In this mode, the primary circuit would be interrupted at some fixed or variable frequency since a continuous interruption over a period of time would cause unburned fuel-air mixtures to accumulate in the exhaust system and could result in a destructive backfire when circuit continuity is restored. An intermittent interruption would allow

some of the spark plugs to fire some of the time and unburned mixtures would not accumulate. The reduction in engine power for any given engine rpm would be a function of the interruption frequency and the ratio of the open-to-closed circuit time.

The device by itself could be programmed to provide a condition which would progressively deteriorate engine power as a function of time. With a logic circuit, which might sense engine parameters such as rpm, manifold pressure, mass flow or exhaust temperature, engine power could be deteriorated to any desired degree whenever a condition is sensed which reflects the existence of high engine power or the attempt to attain high engine power.

2. Electrical resistor mode. In this mode, the current flow through the primary circuit would be restricted to reduce the voltage output from the coil to a level which would be insufficient to fire all or most of the spark plugs some of the time. Since the gap resistance of the spark plugs is a function of engine power, at any given reduction in voltage level, misfire would be most prevalent at the wide open throttle condition.

To cause the vehicle to slow down and stop would require a progressive degradation of the voltage available at the spark plugs. This could be accomplished by a programmed increase in the primary circuit resistance or by the logic circuit. By sensing the appropriate engine parameters, the logic circuit could also effect step changes in the voltage level to cause the disabling to be more effective whenever a significant increase in engine power is demanded.

NOTES

1. "A Study of the Problem of Hot Pursuit by the Police," by Edmund F. Fennessy et al, The Center for the Environment, Hartford, Connecticut, July 1970.
2. "Societal Costs of Motor Vehicle Accidents, Preliminary Report," U.S. Department of Transportation, April 1972.

END

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